PEDAGOGICAL PERSPECTIVE | RESEARCH ARTICLE

An analysis of the science curriculum within the education model of the Türkiye century based on the SOLO taxonomy

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ABSTRACT

The science curriculum, updated in 2024, includes comprehensive reforms to promote interdisciplinary integration in teaching, develop higher-order thinking skills, and strengthen student-centered learning. Determining the extent to which these innovations reflect the cognitive depth of learning outcomes is strategically important for evaluating the curriculum's effectiveness in both its theoretical and practical dimensions. Within this framework, the SOLO Taxonomy provides an opportunity to objectively classify learning outcomes by structure, scope, and cognitive complexity, thereby revealing the cognitive profile of teaching programs in a detailed and systematic manner. In light of these considerations, this study aims to systematically analyze the learning outcomes for grades 3–8 in the 2024-updated science curriculum within the scope of the Türkiye Century Education Model, according to the SOLO taxonomy. The document review method, a qualitative research approach, was used in the study, and the 2024 science curriculum, published electronically by the Ministry of National Education, was examined as the data source. Descriptive analysis was employed to analyze the data obtained. The results indicated that the 585 learning outcomes for grades 3–8 within the curriculum were predominantly represented at the multistructural and relational stages, whereas the extended abstract stage was represented to a limited extent, and the unistructural stage to a very low extent. The expected gradual progression in cognitive development was not achieved across all grades when evaluated by grade levels, with some grades showing a decrease in higher-level cognitive structures and an increase in basic-level structures. This indicates that the curriculum has limitations in maintaining a balance between cognitive levels.

KEYWORDS: Science curriculum; SOLO taxonomy; Türkiye Century Education Model

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1. Introduction

Science, one of the core disciplines included in the education program, aims to equip students with the skills to understand natural phenomena, conduct research using scientific methods, and think critically (Güzel-Yüce & Koç, 2019). This discipline covers subfields such as physics, chemistry, biology, earth sciences, and astronomy, enabling students to learn about nature in its various dimensions and develop scientific process skills such as observation, experimentation, hypothesizing, data collection, and evaluation within the learning experience. It also strengthens problem-solving, creative thinking, and EBR skills, instilling lifelong learning habits. It enables

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theoretical knowledge to be applied to real-life contexts, thereby reinforcing values such as environmental awareness, sustainability, and scientific ethics (Harlen, 2010; Lederman, 2007) through its practical and experimental structure.

The fundamental aim of science education is to systematically and pedagogically transfer the knowledge and methods produced within the scientific discipline so that individuals can acquire scientific thinking skills and effectively apply this knowledge in their daily lives (Tan & Temiz, 2003). Effective science education supports students not only in acquiring knowledge but also in becoming individuals with the skills to question, solve problems, and adapt to innovations. In this context, science education not only improves individuals' quality of life but also significantly contributes to social and sustainable development (Çepni, 2014). In addition, scientific literacy acquired through science education enables individuals to make decisions based on scientific knowledge and approach technological developments with a critical perspective (Çevik & Kaya, 2021). Thus, it helps lay the foundations necessary for developing conscious and responsible behavior at the individual and social levels. The achievement of science education goals and the effective acquisition of scientific process skills by students depend on implementing a science curriculum aligned with these objectives, kept up to date, and grounded in scientific foundations. The science curriculum includes objectives for students related to the field of science; content structured in line with the intended outcomes; activities to be implemented; methods and tools; and assessment criteria that indicate the extent to which the objectives have been achieved (Bümen, 2006).

As of 2024, the science curriculum in Türkiye has been updated and integrated into educational and teaching processes within the framework of the Türkiye Century Education Model. This model aims to develop scientific thinking skills, raise environmental awareness, and instill a consciousness of sustainable living in students (MEB, 2025). The Türkiye century education model aims to restructure Türkiye's education system to meet the requirements of the 21st century by integrating national and cultural values with modern science and technology, and by promoting reforms in educational opportunity, digitalization, research, and professional development. The model aims to develop students into innovative, creative individuals who can adapt to global competition, thereby playing a central role in sustainable development and global success (Diktaş et al., 2025). When examining the innovations brought by this model, it is expected that it will make a significant contribution to the process of preparing individuals for the 21st century, particularly in the field of science education, by presenting literacy skills as a clear and systematic set of competencies, emphasizing the importance of skills, values, and literacy, and adopting a guiding approach on how to integrate them into life (Bilir, 2025). Indeed, it has been emphasized that adopting a skill-based approach, creating a student model with virtues and competencies, and incorporating the virtues-values-actions model into the curriculum are highly valuable for educating students for the 21st century (Yıldırım & Çalışkan, 2024).

The curriculum guides the teaching process and clarifies assessment criteria by using taxonomy models that hierarchically classify cognitive levels to systematically and measurably determine student learning outcomes (Avcı et al., 2021). In this context, the SOLO taxonomy provides an effective tool for assessing the quality of learning outcomes at the prestructural, unistructural, multistructural, relational, and extended abstract stages, revealing the depth and complexity of the learning outcomes of curriculum and thus enriching the design and implementation of curriculum to include not only the acquisition of knowledge but also its interpretation and application to new situations (Biggs & Collis, 1982).

At the prestructural stage, the first level of the SOLO taxonomy, students have not developed a meaningful understanding, and their knowledge is scattered and disorganized; therefore, their knowledge is insufficient to enable them to reach the correct conclusion (Brabrand & Dahl, 2009). The unistructural stage is the second level of the SOLO taxonomy, and at this level, students approach their achievements and knowledge from only one perspective; that is, they try to understand concepts by focusing on a specific aspect of the question or information presented to them (Lister et al., 2006). The multistructural stage is the third level in the SOLO taxonomy. At this stage, the subject is presented to the student in a way that allows it to be approached from different angles, and the student can evaluate various aspects without establishing connections among the subjects (Gezer & İlhan, 2015). The relational stage constitutes the fourth level of the SOLO taxonomy, and at this stage, students can integrate the parts into a whole by establishing meaningful connections between the knowledge presented to them, and they can also develop an in-depth understanding by establishing cause-and-effect relationships between pieces of knowledge (Biggs & Collis, 1982). The extended abstract stage represents the highest and final stage of the SOLO taxonomy; at this stage, students can structure the knowledge they have learned at a metacognitive level and develop creative and original ideas based on existing knowledge (Lake, 1999). In addition, to determine the level of each stage in the SOLO taxonomy, except for the prestructural step, Biggs (2003) and Burnett (1999) defined indicator verbs (Gezer & İlhan, 2014).

2. Literature Review

In the literature, studies have been conducted based on the SOLO taxonomy. For example, Dönmez and Zorluoğlu (2020) examined the learning outcomes for grades 6, 7, and 8 in the 2018 middle school science curriculum within the SOLO taxonomy framework. Their analysis indicated that most learning outcomes were at the uni-structural and relational levels, whereas the multi-structural and extended abstract levels were less prevalent. Cihan and Doruk (2024) analyzed the 2024 secondary school mathematics curriculum according to the SOLO taxonomy and cognitive demand levels. Their findings showed that the curriculum's learning outcomes were predominantly at the extended-abstract level, followed by the relational, multi-structural, and uni-structural levels. Korkmaz and Ünsal (2017) examined 11th-grade learning outcomes and assessment questions in the 2010 Sociology Curriculum using the SOLO Taxonomy. Their results revealed that both learning outcomes and assessment questions covered all SOLO levels, with the outcomes concentrated primarily at the relational and uni-structural levels and the assessment questions primarily at the uni-structural and multi-structural levels. Doğan (2020) analyzed the 2018 elementary school mathematics curriculum learning outcomes of 2018 based on the SOLO taxonomy. The findings indicated that most outcomes were at the uni-structural and multi-structural levels, few were relational, and none were at the extended abstract level. Ağçam and Babanoğlu (2018) examined learning outcomes in the 2018 English curriculum for primary and secondary education using the SOLO Taxonomy. Their results showed that outcomes were predominantly at the uni- and multi-structural levels in primary education and at the multi- and relational levels in secondary education, indicating that the programs focused more on lower-order cognitive skills. Brabrand and Dahl (2009) used the SOLO Taxonomy to analyze the learning outcomes of undergraduate and graduate science programs at the Faculties of Science at Aarhus University and the University of Southern Denmark in 2007. Their findings revealed a clear progression in competence from undergraduate to graduate levels and highlighted the strong influence of educational traditions and subjects on program structures. Erbudak (2025) examined the measurement and assessment questions in 4th–7th-grade social studies textbooks used in primary and secondary schools in Turkey during the 2024–2025 academic year, using the SOLO Taxonomy. The study found that most questions were at the uni-structural level; the fewest were at the extended abstract level; relational and multi-structural questions were limited in number; and there was no significant change in the cognitive level of questions as the grade level increased.

3. Purpose and Significance of the Study

The primary aim of this study is to systematically analyze the learning outcomes for grades 3–8 in the 2024 revised Science Curriculum according to SOLO levels. In addition, this study aims to determine the cognitive complexity levels of the curriculum's learning outcomes, reveal their distribution across grade levels and content areas, and provide insights into how this distribution could foster higher-order thinking skills in students. The 2024 Science Curriculum includes significant changes designed to promote interdisciplinary integration in teaching processes, enhance higher-order thinking skills, and strengthen SCL approaches. Determining the extent to which these changes are reflected in the cognitive depth of learning outcomes is a strategic necessity for evaluating the curriculum's effectiveness in both theoretical and practical dimensions. Furthermore, systematically examining the grade-level learning outcomes of the previous curriculum in terms of both their current SOLO taxonomy levels and the ideal SOLO levels expected of students will enable a more comprehensive assessment of the effects of curriculum changes on cognitive complexity and higher-order thinking skills.

The SOLO Taxonomy enables the objective classification of learning outcomes by structure, scope, and cognitive complexity, thereby providing a detailed profile of curricula's cognitive characteristics. A review of the existing literature indicates that no study has analyzed the 2024 revised curriculum based on the SOLO taxonomy. In this context, beyond addressing a significant gap in the literature, the study is expected to provide comprehensive, concrete, measurable, and comparable data to curriculum developers, educators, and researchers, thus laying a scientifically grounded foundation for both curriculum development and the improvement of educational practices. Furthermore, serving as an effective guide across a wide spectrum—from policy-making processes to classroom practices—this research represents a pioneering study that provides a reference framework for understanding and enhancing the curriculum's cognitive architecture at both theoretical and practical levels.

In line with these considerations, the learning outcomes in the 2024 science curriculum, developed within the scope of the Türkiye Century Education Model, were examined using the SOLO taxonomy, and the following questions were addressed.

- How are the science curriculum learning outcomes distributed according to the SOLO taxonomy?
- How are the 3rd-grade learning outcomes distributed according to the SOLO taxonomy?
- How are 4th-grade learning outcomes distributed according to the SOLO taxonomy?
- How are 5th-grade learning outcomes distributed according to the SOLO taxonomy?
- How are 6th-grade learning outcomes distributed according to the SOLO taxonomy?
- How are 7th-grade learning outcomes distributed according to the SOLO taxonomy?
- How are the 8th-grade learning outcomes distributed according to the SOLO taxonomy?

4. Method

4.1. Research Design

The document review method, a qualitative research approach, was employed in this study. Document review is a qualitative method that systematically and meticulously examines the content of written materials to obtain comprehensive and in-depth knowledge of a particular subject (Bowen, 2009). This method, which allows the evaluation of both printed and electronic sources, contributes to the construction of meaning, the development of a conceptual framework, and the production of empirical knowledge (Corbin & Strauss, 2008). In this context, document review goes beyond merely providing a superficial description of existing data, encompassing the information's interpretation and contextualization.

4.2. Study Sample

In this study, the Science Curriculum, which was updated in 2024 within the framework of the Türkiye Century Education Model and published electronically by the Ministry of National Education (MEB), the institution responsible for preparing and publishing curricula in Türkiye, was examined. Within the scope of the study, the https://tymm.meb.gov.tr website was accessed, the science course was selected from the curriculum section, and a total of 585 learning outcomes from the units at the 3rd–8th grade levels were identified.

4.3. Data Analysis

Descriptive analysis was employed to examine the data. Descriptive analysis is a qualitative research method that systematically organizes and interprets data within the framework of predetermined themes (Yıldırım & Şimşek, 2018). In this approach, the data obtained are grouped under meaningful themes, described with direct quotations, and presented within an interpretive framework (Miles & Huberman, 1994). During the analysis, all findings were first categorized by grade level and related units, and recorded in Microsoft Excel. Each learning outcome was evaluated by the SOLO stage it corresponded to and classified by content. To ensure reliability, the opinions of two experts, one in the field of social studies education and the other in the field of science education, were sought, both of whom had previously conducted analyses related to the SOLO taxonomy. The study's reliability was calculated using the formula developed by Miles and Huberman (1994): [Reliability = Agreement / (Agreement + Disagreement) × 100]. The result was 94.4%, indicating that the analyses were highly reliable. The SOLO levels corresponding to the learning outcomes for each grade level were identified, and the findings were presented graphically and interpreted descriptively. Within this framework, the analysis provided insights into the curriculum's cognitive competence levels within the scope of the Türkiye Century Education Model, systematically revealing the structural depth and developmental stages of the curriculum's learning outcomes. The indicator verbs identified in the studies by Biggs (2003) and Brabrand & Dahl (2009) were used to classify the learning outcomes according to the SOLO taxonomy. Table 1 presents the distribution of these indicator verbs across the SOLO stages.

Table 1 ***Indicator Verbs Defined for the SOLO Taxonomy Stages***

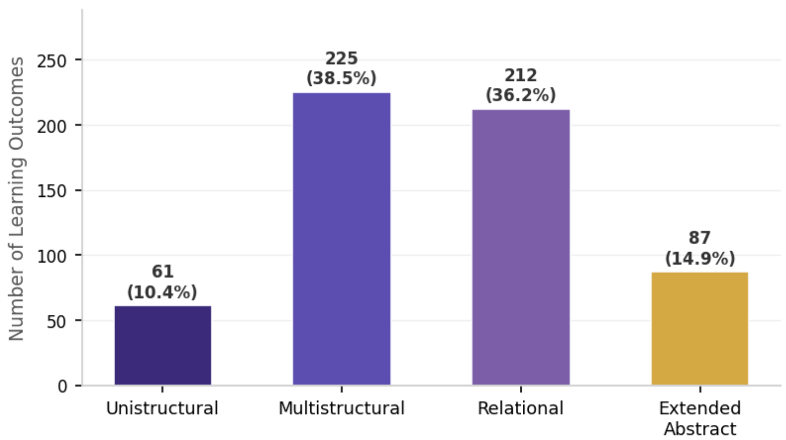
Unistructural	Multistructural	Relational	Extended Abstract
Memorize	Classify	Applying a given theory to a related field	Theorize
Identify	Describe	Conclude	Hypothesize
Recognize	List	Integrate	Generalize
Count	Report	Summarize	Create
Define	Discuss	Analyze	Generate
Draw	Illustrate	Review	Compose
Find	Select	Explaining the causes	Invent
Label	Narrate	Argue / Predict	Originate / Creating an original case
Match	Compute	Transfer	Prove from the first principle
Name / Quote	Sequence / Outline	Substantiate	Solve from the first principle
Recall	Separate	Construct	Reason
Recite	Combine	Exemplify	Reflect
Follow a simple command	Account for / Apply	Design / Derive	Imagine / Evaluate
Arrange / Decide	Method / Execute	Adapt / Structure	Assess / Interpret
Note / Seek	make / Use method	Make a plan / Relate	Reflect / Perspectivate
Choose / Sketch	Solve / Conduct	Implement / Compare	Criticize / Judge
Pick / Order	Prove / Complete	Contrast / Differentiate	
	Process / Report	Organize / Debate	
	Express / Characterize	Make a case / Construct	
		Review and rewrite / Examine	
		Paraphrase / Translate	
		Solve a problem / Question	
		Argue	

5. Findings

5.1. Distribution of Science Curriculum Learning Outcomes According to the SOLO Taxonomy

The distribution of the 585 learning outcomes in the science curriculum, according to the SOLO taxonomy, is shown in Figure 1.

Figure 1 ***Distribution of Science Curriculum Learning Outcomes According to the SOLO Taxonomy***

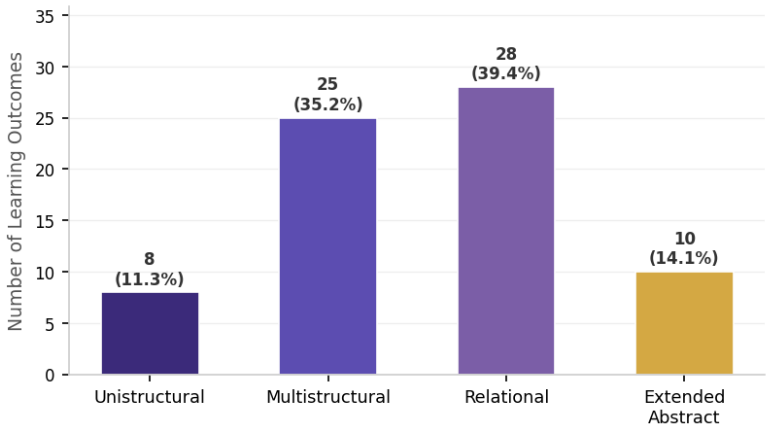


As shown in Figure 1, 61 of the learning outcomes (10.4%) are unistructural, 225 (38.5%) are multistructural, 212 (36.2%) are relational, and 87 (14.9%) are extended abstract.

5.2. Distribution of 3rd Grade Learning Outcomes According to the SOLO Taxonomy

The distribution of 71 learning outcomes at the 3rd grade level according to the SOLO taxonomy is shown in Figure 2.

Figure 2 ***Distribution of 3rd-Grade Learning Outcomes According to SOLO Taxonomy***



As shown in Figure 2, 8 (11.3%) of the 3rd-grade learning outcomes were unistructural, 25 (35.2%) were multistructural, 28 (39.4%) were relational, and 10 (14.1%) were extended abstract. For illustrative purposes, Table 2 presents the 3rd-grade learning outcomes, the corresponding SOLO taxonomy stages, and their justifications.

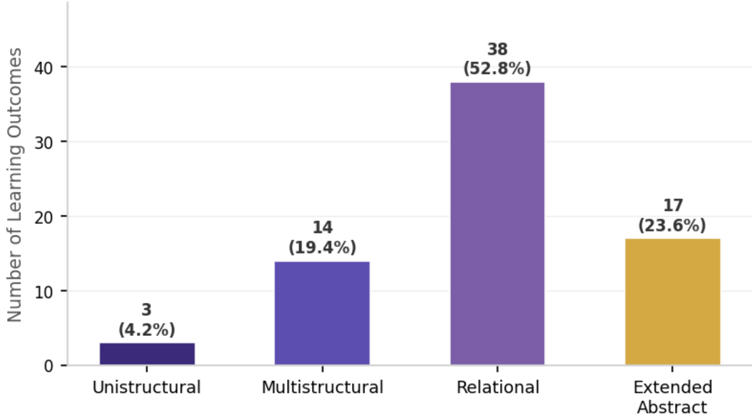
Table 2 ***Selected Examples from 3rd Grade Learning Outcomes, SOLO Taxonomy Levels, and Justifications***

Unit	Learning Outcomes	SOLO Stages	Justifications
The Scientific Discovery Journey	FB.3.1.2.a: He/she gathers knowledge about scientists.	Unistructural	This learning outcome was assessed at the unistructural stage because it only involves the ability to gather knowledge and does not require association or analysis.
Journey to the Living World	FB.3.2.1.c: He/she groups living things.	Multistructural	This learning outcome has been evaluated at a multistructural stage because it involves classifying living things according to multiple characteristics and using multiple pieces of knowledge.
Geoscientists in Action	FB.3.3.2.b: He/she establishes relationships between the stages of the process.	Relational	This learning outcome has been assessed at the relational stage because it involves developing a holistic understanding by establishing relationships between the stages of the process.
Let's Get to Know the Substance, Mix, and Separate	FB.3.4.2.a: He/she designs experiments related to methods that can be used to separate mixtures.	Extended Abstract	This learning outcome was assessed at the extended abstract stage, as it involves adapting knowledge to a new situation and abstracting when designing experiments using methods for separating mixtures.

5.3. Distribution of 4th Grade Learning Outcomes According to the SOLO Taxonomy

The distribution of 72 learning outcomes at the 4th grade level according to the SOLO taxonomy is shown in Figure 3.

Figure 3 ***Distribution of 4th-Grade Learning Outcomes According to SOLO Taxonomy***



As shown in Figure 3, 3 of the 4th-grade achievements (4.2%) are unistructural, 14 (19.4%) are multistructural, 38 (52.8%) are relational, and 17 (23.6%) are extended abstract. For illustrative purposes, Table 3 shows the 4th-grade learning outcomes and the corresponding SOLO taxonomy stages and justifications.

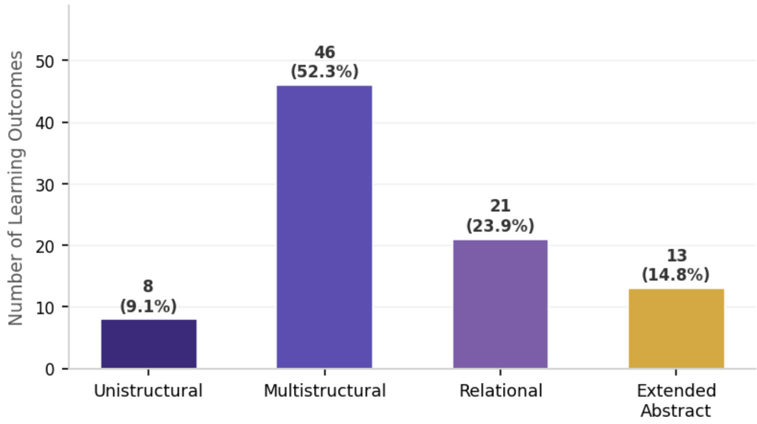
Table 3 ***Selected Examples from 4th Grade Learning Outcomes, SOLO Taxonomy Levels, and Justifications***

Unit	Learning Outcomes	SOLO Stages	Justifications
Transformation of Matter	FB.4.4.1.b: Records data related to substance transformation.	Unistructural	This achievement has been evaluated at an unistructural stage because it involves the student recording data on the transformation of substances and does not require establishing relationships or performing analysis.
I Eat Healthily	FB.4.2.2.b: Identifies the common characteristics of foods.	Multistructural	This learning outcome has been assessed at a multistructural stage because it involves the student identifying multiple common characteristics in foods and using multiple pieces of knowledge.
The Journey to Science	FB.4.1.1.c: Evaluates the conclusions reached regarding the scientific characteristics.	Relational	This learning outcome has been assessed at the relational stage because it involves the student analyzing and evaluating conclusions reached regarding the characteristics of science.
Discovering Magnets	FB.4.5.3.b: Develops a model that can be used to answer a question or problem.	Extended Abstract	This learning outcome was evaluated at the extended abstract stage because it involves adapting knowledge to a different situation by developing a new model that can be used to answer the student's question or problem.

5.4. Distribution of Learning Outcomes in the 5th Grade According to the SOLO Taxonomy

The distribution of 88 learning outcomes at the 5th grade level according to the SOLO taxonomy is shown in Figure 4.

Figure 4 ***Distribution of 5th-Grade Learning Outcomes According to SOLO Taxonomy***



As shown in Figure 4, 8 (9.1%) of the 5th grade learning outcomes were unistructural, 46 (52.3%) were multistructural, 21 (23.9%) were relational, and 13 (14.8%) were extended abstract. For illustrative purposes, Table 4 shows the 5th grade learning outcomes and the corresponding SOLO taxonomy stages and justifications.

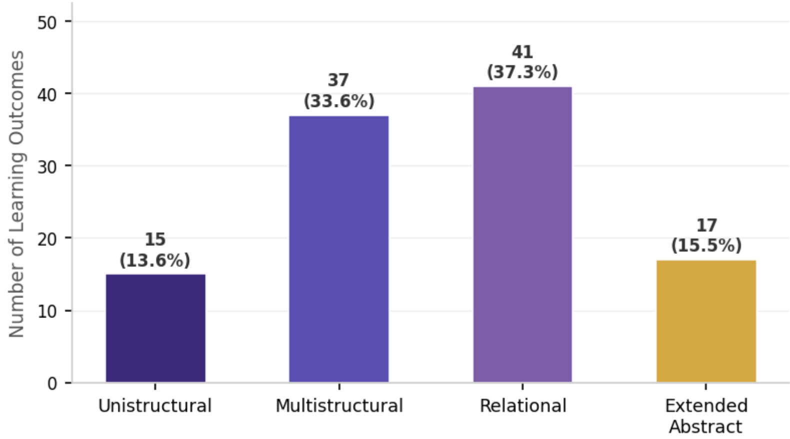
Table 4 ***Selected Examples from 5th Grade Learning Outcomes, SOLO Taxonomy Levels, and Justifications***

Unit	Learning Outcomes	SOLO Stages	Justifications
Neighbors in the Sky and Us	FB.5.1.2.1.b: He/she records data on the characteristics of the Moon and its rotational and orbital movements.	Unistructural	This learning outcome has been assessed at a unistructural stage because it involves the student recording data on the characteristics of the Moon and its rotational and orbital movements, and it does not require the student to establish relationships or perform analysis.
Let's Get to Know the Force	FB.5.2.2.1.a: He/she defines the mass and weight properties.	Multistructural	This learning outcome has been assessed at a multistructural stage because it involves the student defining multiple characteristics related to the concepts of mass and weight.
Nature of the Substance	FB.5.5.3.1.b: Compares observations- and non-observations-based propositions.	Relational	This learning outcome is assessed at the relational level, as it requires the student to compare and relate observation- and non-observation-based propositions.
Electricity in our lives	FB.5.6.1.2.a: He/she designs an experimental system that matches the electrical circuit he/she has drawn.	Extended Abstract	This learning outcome was evaluated at an extended abstract stage because it involves the student adapting their knowledge to a new situation by designing an experimental setup appropriate to the electrical circuit they have drawn.

5.5. Distribution of 6th Grade Learning Outcomes According to the SOLO Taxonomy

The distribution of 110 learning outcomes at the 6th grade level according to the SOLO taxonomy is shown in Figure 5.

Figure 5 ***Distribution of 6th-Grade Learning Outcomes According to SOLO Taxonomy***



As shown in Figure 5, 15 of the 6th grade learning outcomes (13.6%) are unistructural, 37 (33.6%) are multistructural, 41 (37.3%) are relational, and 17 (15.5%) are extended abstract. For illustrative purposes, Table 5 shows the 6th grade learning outcomes and the corresponding SOLO taxonomy stages and justifications.

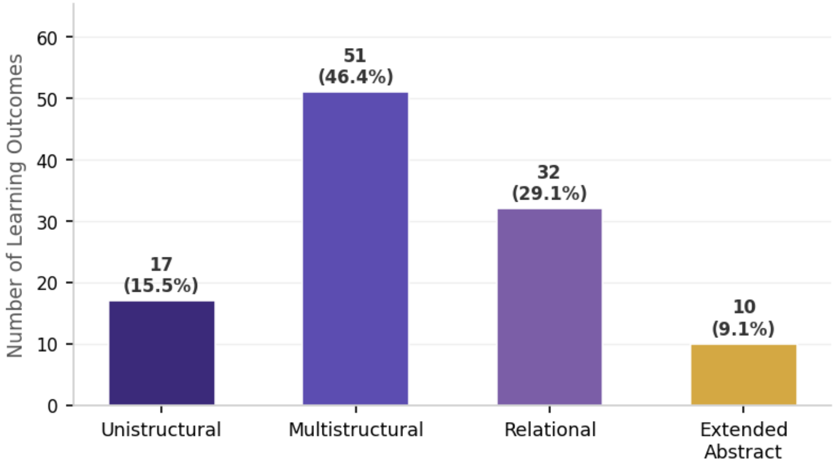
Table 5 ***Selected Examples from 6th Grade Learning Outcomes, SOLO Taxonomy Levels, and Justifications***

Unit	Learning Outcomes	SOLO Stages	Justifications
Solar System and Eclipses	FB.6.1.2.1.b: He/she records data collected during solar and lunar eclipses.	Unistructural	This learning outcome has been assessed at an unistructural stage because it involves the student recording data related to solar and lunar eclipses and does not require establishing relationships or performing analysis.
Influence of Force	FB.6.2.2.1.a: Determines the characteristics related to the speed and velocity concepts.	Multistructural	This learning outcome has been assessed at a multistructural stage because it involves students identifying multiple characteristics related to the concepts of speed and velocity.
Systems in Living Things	FB.6.3.1.4.c: Data on the basic factors affecting reproduction, growth, and development in animals are evaluated.	Relational	This learning outcome has been assessed at the relational stage because it involves the student analyzing data related to the basic factors affecting animal reproduction, growth, and development.
Lighting and Colors	FB.6.4.3.4.b: Reasoning about innovative applications of solar energy in daily life and technology.	Extended Abstract	This learning outcome was assessed at an extended abstract stage because it involves the student using knowledge in a new context by reasoning about innovative applications of solar energy in everyday life and technology.

5.6. Distribution of 7th Grade Learning Outcomes Based on the SOLO Taxonomy

The distribution of 110 learning outcomes at the 7th grade level according to the SOLO taxonomy is shown in Figure 6.

Figure 6 ***Distribution of 7th-Grade Learning Outcomes According to the SOLO Taxonomy***



As shown in Figure 6, 17 of the 7th-grade learning outcomes (15.5%) were unistructural, 51 (46.3%) were multistructural, 32 (29.1%) were relational, and 10 (9.1%) were extended abstract. For illustrative purposes, Table 6 presents the 7th-grade learning outcomes, the corresponding SOLO taxonomy stages, and their justifications.

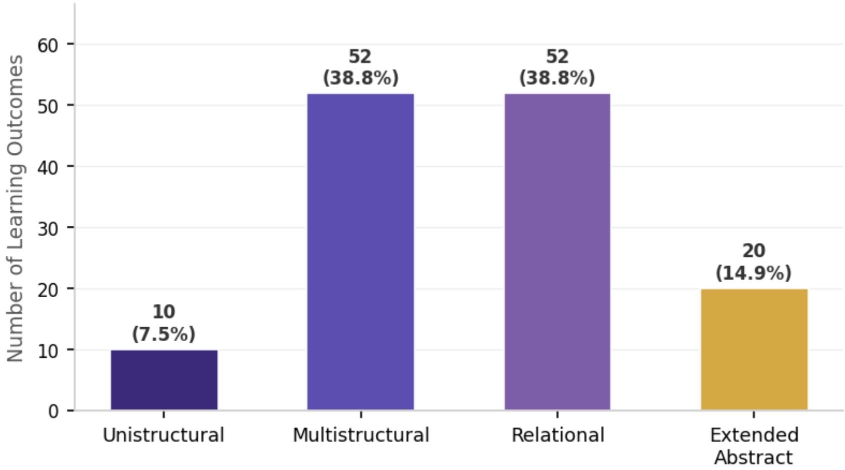
Table 6 ***Selected Examples from 7th Grade Learning Outcomes, SOLO Taxonomy Levels, and Justifications***

Unit	Learning Outcomes	SOLO Stages	Justifications
A Journey into the Nature of Substances	FB.7.5.1.2.c: He/she gathers knowledge about atoms from the past to the present.	Unistructural	This learning outcome has been evaluated at an unistructural stage because it involves the student gathering knowledge about atoms from the past to the present and does not require establishing connections or performing analysis.
Refraction of the Light and Lenses	FB.7.4.2.2.c: He/she groups the areas of lens application.	Multistructural	This learning outcome has been evaluated at a multistructural stage because it involves the student categorizing the areas of lens application according to multiple characteristics.
Electrification	FB.7.6.1.1.c: Verifies the knowledge he has about electrification.	Relational	This learning outcome has been evaluated at the relational stage because it involves the student evaluating the accuracy of the knowledge they have found about electrification.
Sustainable living and recycling	FB.7.7.2.1.b: He/she develops models to find solutions for the efficient use of resources.	Extended Abstract	This learning outcome was assessed at an extended abstract stage because it involves the student adapting knowledge to a new situation by developing a model to find solutions for the economical use of resources.

5.7. Distribution of 8th Grade Learning Outcomes According to the SOLO Taxonomy

The distribution of 134 learning outcomes at the 8th grade level according to the SOLO taxonomy is shown in Figure 7.

Figure 7 *Distribution of 8th-Grade Learning Outcomes According to SOLO Taxonomy*



As shown in Figure 7, 10 of the 8th-grade learning outcomes (7.5%) are unistructural, 52 (38.8%) are multistructural, 52 (38.8%) are relational, and 20 (14.9%) are extended abstract. For illustrative purposes, Table 7 presents the 8th-grade learning outcomes, the corresponding SOLO taxonomy stages, and their justifications.

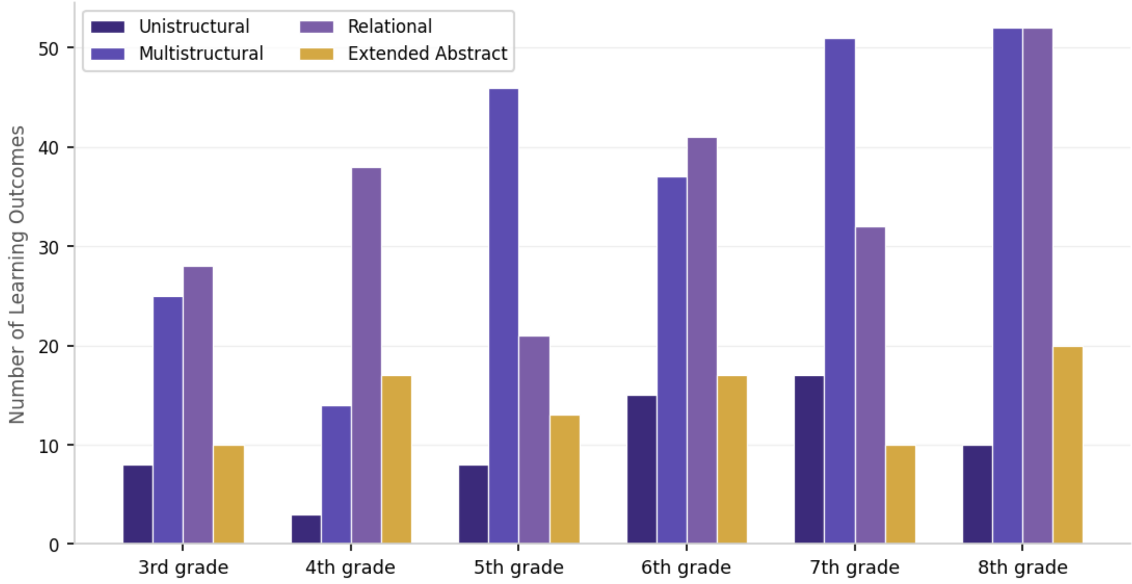
Table 7 *Selected Examples from 8th Grade Learning Outcomes, SOLO Taxonomy Levels, and Justifications*

Unit	Learning Outcomes	SOLO Stages	Justifications
The Mystery of Life	FB.8.3.4.1.b: He/she finds knowledge about mutation.	Unistructural	This learning outcome has been assessed at an unistructural stage because it involves the student finding knowledge about mutation and does not require establishing connections or performing analysis.
The Force that Makes Life Easier	FB.8.2.1.1.a: Determines the characteristics of the simple machines.	Multistructural	This learning outcome has been assessed at a multistructural stage because it involves the student using multiple pieces of knowledge by identifying multiple attributes, such as the functions and characteristics of simple machines.
The Sound World	FB.8.4.1.2.b: He/she analyzes data obtained by observing how the same sound is heard differently in different environments.	Relational	This learning outcome was assessed at the relational stage because it involves the student analyzing observational data related to how the same sound is perceived differently in different environments and establishing relationships between the data.
Periodic Table and the Interaction of Substances	FB.8.5.4.4.a: He/she designs experiments to demonstrate the effects of acids and bases on various substances.	Extended Abstract	This learning outcome was assessed at an extended abstract stage because it involved the student adapting their knowledge to a new situation by designing an experiment to demonstrate the effects of acids and bases on various substances.

5.8. Distribution of Science Curriculum Outcomes by Grades According to SOLO Taxonomy

The distribution of 585 learning outcomes according to SOLO taxonomy by grades is shown in Figure 8.

Figure 8 ***Distribution of Learning Outcomes by Grades According to SOLO Taxonomy***



6. Discussion, Conclusion, and Recommendations

6.1. Discussion and Conclusion Regarding the First Sub-Problem

When examining the distribution of 585 learning outcomes according to the SOLO taxonomy, the highest proportion was in the multistructural category (38.5%), followed by the relational (36.2%), the extended abstract (14.9%), and the unistructural (10.4%). These results indicate that the curriculum includes learning outcomes that can assess students' cognitive skills from multiple perspectives and enable them to organize knowledge relationally. The combined presence of multi-structural and relational levels at 74.7% demonstrates that the curriculum is focused on intermediate- and higher-order cognitive levels. However, the relatively limited proportion of learning outcomes at the extended-abstract level suggests that students' potential to develop higher-order competencies, such as knowledge restructuring, critical thinking, creative problem-solving, and applying knowledge to new situations, is restricted. The low proportion of uni-structural outcomes (10.4%) suggests that basic knowledge outcomes are kept limited, which may hinder progression to higher-order cognitive levels without a solid understanding of fundamental concepts. In a similar study, Sağlamöz and Soysal (2021) analyzed the 2018 primary school science curriculum outcomes based on the revised Bloom's Taxonomy and indicated that outcomes at the remembering and understanding levels required "low" cognitive demand, those at the applying and analyzing levels required "medium" demand, and those at the evaluating and creating levels required "high" cognitive demand. The highest proportion, 39.82%, was found in the understanding dimension. These data indicate that both curricula primarily target intermediate- and higher-order cognitive processes, although the relatively low proportion at the highest cognitive levels suggests limited potential for developing advanced skills.

The SOLO taxonomy allows learning outcomes to be classified not only in terms of cognitive processes but also based on the structural complexity and qualitative depth of knowledge, revealing students' potential to establish inter-conceptual relationships, integrate knowledge, and develop higher-order thinking skills (Biggs & Collis, 1982). In contrast, the revised Bloom's Taxonomy focuses on the hierarchical ordering of cognitive processes but offers limited opportunities to systematically assess the structural integrity of knowledge and its applicability across contexts (Anderson &

Krathwohl, 2001). In this respect, the SOLO Taxonomy offers a more comprehensive and robust framework for analyzing the extent to which the curriculum includes relational and extended abstract outcomes representing higher-order cognitive processes and the potential for students to develop critical, creative, and problem-solving skills.

6.2. Discussion and Conclusion Regarding the Second Sub-Problem

When examining the learning outcomes of the 3rd grade, the highest proportion was relational (39.4%), followed by multistructural (35.2%), extended abstract (14.1%), and unistructural (11.3%). The fact that the unistructural learning outcomes, representing basic cognitive processes, remain at this level in 3rd grade, the starting level of science education, suggests deficiencies in establishing a solid foundation for students' learning. This situation may indicate that students are not adequately supported, especially in the stages of recognizing basic concepts and acquiring knowledge for the first time. Conversely, the high proportions of relational and multistructural stages indicate that the curriculum tends to guide students toward more complex thinking processes at early stages. However, this approach may make it difficult to transition to higher-order cognitive processes without adequately reinforcing basic cognitive skills. Therefore, increasing the number of unistructural learning outcomes in 3rd grade is important to ensure the learning process is grounded in a solid foundation.

In a similar study, Karakuyu (2021) analyzed 3rd-grade outcomes of the 2018 science curriculum using the Haladyna taxonomy. The analysis revealed that 57.58%, 6.06%, and 30.30% of the learning outcomes were categorized in the comprehension and problem-solving stages, 30.30% in the critical-thinking stage, and 6.06% in the creativity stage. Accordingly, the 3rd-grade learning outcomes address lower-order cognitive skills such as comprehension and problem-solving, which is appropriate considering the age and developmental characteristics of 3rd-grade students. From this perspective, a clear distinction is observed between the findings of this study and those of Karakuyu (2021). The increase in the proportion of learning outcomes focused on higher-order cognitive processes at the 3rd-grade level in the 2024 Science Curriculum aligns with the contemporary educational approach that seeks to develop complex thinking skills at an early age. However, advancing to higher-order cognitive processes without adequately reinforcing basic-level conceptual knowledge and skills can increase students' cognitive load and lead to conceptual gaps in learning. Therefore, structuring the curriculum to develop both basic and higher-order skills in a balanced manner is critical for holistically supporting students' cognitive development.

6.3. Discussion and Conclusion Regarding the Third Sub-Problem

When examining the learning outcomes for 4th grade, the highest proportion was relational (52.8%), followed by extended abstract (23.6%), multistructural (19.4%), and unistructural (4.2%). Compared to the 3rd-grade learning outcomes, those at the relational stage increased significantly from 39.4% to 52.8%, and those at the extended abstract stage rose from 14.1% to 23.6%. In contrast, the learning outcomes at the multistructural stage decreased from 35.2% to 19.4%, and those at the unistructural stage declined from 11.3% to 4.2%. This indicates that students have made significant progress in higher-order thinking skills. However, the fact that learning outcomes at the unistructural stage, which represent basic cognitive processes, remain at a very low rate of 4.2% raises concerns about whether the fundamental building blocks of learning are sufficiently emphasized. Especially in the early stages of subjects such as science, where conceptual foundations play a critical role, students must establish a solid learning foundation by presenting basic knowledge and skills in a balanced and systematic manner. In this context, the curriculum should provide a more balanced distribution of learning outcomes across different cognitive levels. In their study, Doğan and Burak (2018) examined

46 learning outcomes at the 4th-grade level in the 2013 science curriculum, using the revised Bloom's taxonomy, and reported that the comprehension and application levels were predominant, whereas higher-order cognitive processes, such as analysis and evaluation, were more limited. In this regard, the finding that the 4th-grade learning outcomes in the present study were most frequently at the relational stage, compared with Doğan and Burak (2018), indicates that the 2024 updated curriculum places a marked emphasis on higher-order cognitive objectives. However, the low proportion of learning outcomes at the unistructural stage suggests that the basic knowledge and comprehension stages are insufficiently reinforced. As emphasized in the literature (Doğan & Burak, 2018; Biggs & Collis, 2014), a gradual transition from lower- to higher-order cognitive processes is critical for learning sustainability. Therefore, while the curriculum strengthens higher-order cognitive objectives, lower-order cognitive structures should not be overlooked.

6.4. Discussion and Conclusion Regarding the Fourth Sub-Problem

When examining the learning outcomes of 5th grade, it was determined that the highest proportion was in the multistructural category (52.3%), followed by the relational (23.9%), extended abstract (14.8%), and unistructural (9.1%). Compared to the 4th grade, the learning outcomes at the multistructural stage increased significantly from 19.4% to 52.3%. In contrast, the learning outcomes at the relational stage decreased from 52.8% to 23.9%, and those at the extended abstract stage declined from 23.6% to 14.8%. In addition, the learning outcomes at the unistructural stage increased from 4.2% to 9.1%. The reduction in relational and extended abstract outcomes, which represent higher-order cognitive processes, is noteworthy in light of expectations for cognitive development. While an increase in these outcomes is expected as grade level progresses, the concentration of multistructural outcomes and the rise in unistructural outcomes in 5th grade indicate inconsistencies in the curriculum's cognitive development sequence. In a similar study, Ozcan and Kaptan (2019) examined the 2018 science curriculum according to the revised Bloom's taxonomy. The analysis showed that 20% of the learning outcomes were in the knowledge dimension, 22.8% in comprehension, 2.9% in problem-solving, 51.4% in scientific process skills, 2.9% in the science-technology-society-environment domain, and 0% in attitudes and values at the 5th grade level. Considering these two findings together, it can be observed that in the 2024 science curriculum, 5th-grade learning outcomes are predominantly at the multistructural stage according to the SOLO taxonomy, whereas in the 2018 science curriculum at the same grade level, they were mostly concentrated in the scientific process skills domain according to the revised Bloom's taxonomy. The multistructural stage aligns with scientific process skills by requiring the integration of multiple pieces of information; however, the decline in higher-order cognitive processes, such as the relational and extended abstract stages, indicates that students' ability to achieve deep understanding and to apply knowledge across contexts is insufficiently supported. Therefore, the predominance of middle-order cognitive processes in the structure of the curriculum's learning outcomes limits the development of higher-order structures, resulting in deviations from the expected upward trajectory in the cognitive progression hierarchy.

6.5. Discussion and Conclusion Regarding the Fifth Sub-Problem

When examining the learning outcomes of 6th grade, it was determined that the highest proportion was relational (37.3%), followed by multistructural (33.6%), extended abstract (15.5%), and unistructural (13.6%). The learning outcomes at the relational stage increased significantly from 23.9% to 37.3% compared with the 5th grade. The outcomes at the multistructural stage decreased markedly from 52.3% to 33.6%, whereas those at the extended abstract stage rose slightly from 14.8% to 15.5%. However, the outcomes at the unistructural stage increased from 9.1% to 13.6%, contradicting the expected decrease in cognitive development. In this context, the increase in the rate of unistructural outcomes in the 6th-grade curriculum suggests that learning outcomes are concentrated in basic cognitive processes and that higher-order thinking skills are not supported at the expected level. In a similar study, Cangüven et al. (2017) examined the 2017 draft science curriculum according to Bloom's revised taxonomy. Based on their analysis, the 6th-grade learning outcomes were distributed across the remembering, understanding, application, analysis, and evaluation levels of the cognitive domain at 11%, 40%, 20%, 7%, and 3%, respectively. Accordingly, a parallel exists between the findings of both curricula within the framework of different taxonomies. Both studies indicate that lower-order cognitive processes carry significant weight at the 6th-grade level, whereas higher-order processes remain limited. This situation reveals that higher-order cognitive outcomes are not systematically supported, despite increased grade level, and supports the view that cognitive structuring needs to be enhanced in the curriculum.

6.6. Discussion and Conclusion Regarding the Sixth Sub-Problem

When examining the learning outcomes of 7th graders, the highest proportion was in the multistructural category (46.3%), followed by the relational (29.1%), unistructural (15.5%), and extended abstract (9.1%). Compared with the 6th grade, the learning outcomes at the multistructural stage significantly increased from 33.6% to 46.3%, while the outcomes at the relational stage decreased from 37.3% to 29.1%. The outcomes at the unistructural stage rose from 13.6% to 15.5%, whereas those at the extended abstract stage declined from 15.5% to 9.1%. This distribution indicates a decrease in the levels representing higher-order cognitive processes, whereas the levels covering more basic cognitive processes increased. This suggests that although an increase in higher-order cognitive outcomes would be expected as grade level advances, this expectation was not met in 7th grade, pointing to inconsistencies in the curriculum with respect to cognitive development. In a similar study, Gündöğdu and Aydın (2024) examined the 5th–8th grade learning outcomes of the 2018 science curriculum according to the revised Bloom's taxonomy. The analysis revealed that 69.7% and 30.3% of the learning outcomes were associated with lower-order and higher-order thinking skills, respectively. These parallel results, obtained from different evaluation frameworks such as the SOLO taxonomy and the revised Bloom's taxonomy, indicate that the cognitive demand level in 7th grade is predominantly at the basic and intermediate levels. This situation reveals that students' opportunities to develop higher-order thinking processes are limited and that the curriculum has not achieved the expected increase in the hierarchy of cognitive progression.

6.7. Discussion and Conclusion Regarding the Seventh Sub-Problem

When examining the learning outcomes of 8th graders, it was determined that the highest proportion was in the multistructural and relational stages (38.8% each), followed by the extended abstract (14.9%), and the lowest was in the unistructural stage (7.5%). Compared with the 7th grade, the learning outcomes at the multistructural stage decreased from 46.3% to 38.8%, whereas those at the relational stage increased significantly from 29.1% to 38.8%. The outcomes at the extended abstract stage rose from 9.1% to 14.9%, whereas those at the unistructural stage declined from 15.5% to 7.5%. This distribution indicates a tendency for the stages representing higher-order cognitive processes, such as relational and extended abstract, to increase, whereas the stages covering more basic cognitive processes, such as unistructural and multistructural, generally decrease. However, while higher-order cognitive processes would be expected to be more strongly emphasized at the 8th-grade level, the fact that the multistructural and relational outcomes remain at the highest rates suggests that the curriculum does not fully align with the expected systematic progression in cognitive development. This raises concerns that the multistructural level is insufficiently supported as a transition to higher-order processes and may indicate the need to revise the curriculum regarding cognitive structuring. In support of this view, Acet et al. (2021) examined 8th-grade learning outcomes for the 2018 science curriculum and the LGS questions from 2019 and 2020 using the SOLO taxonomy. Their analysis revealed that the highest proportion of learning outcomes was at the extended abstract stage (34.54%), followed by the relational (32.72%), multistructural (21.81%), and unistructural (10.90%) stages. This difference suggests that in the 2024 science curriculum, the transition to higher-order cognitive levels for the 8th grade has been made more gradual and broad-based; however, this may have relatively reduced the proportion of outcomes at the extended abstract stage, limiting the expected cognitive deepening. Therefore, it can be argued that there is a need for arrangements that more systematically support the transformation of multistructural outcomes into higher-order cognitive processes to achieve the intended cognitive progression in the 2024 science curriculum.

In light of these results, the distribution of science curriculum learning outcomes across the SOLO taxonomy stages shows significant inconsistencies, particularly in achieving the desired balance between lower- and higher-order cognitive processes. This indicates that the planned gradual progression in students' cognitive development is not fully realized and supports the view that the curriculum's cognitive structuring may need reassessment.

In this study, the learning outcomes in the science curriculum within the framework of the Türkiye Century Education Model were analyzed using the SOLO taxonomy levels, yielding the results described above. Based on the findings, a set of recommendations has been proposed for teachers, curriculum developers, and policymakers to enhance the science curriculum, making it more coherent, balanced, and practically applicable.

It is recommended that teachers follow a scaffolded cognitive progression in each grade, building upon the previous level, and integrate learning outcomes at the relational and extended abstract levels—representing higher-order cognitive processes—into their lesson plans. In this context, providing sample activities, scenarios, and performance tasks that target higher-order outcomes may concretely support the development of advanced thinking skills in students.

For curriculum developers, defining a minimum number of learning outcomes that incorporate higher-order cognitive skills for each unit, reorganizing the outcomes by grade level, and including sample activities for their implementation in program documents are recommended. Additionally, establishing interdisciplinary teams composed of experts in cognitive development, assessment, and subject-matter education, and incorporating iterative processes such as pilot implementation, feedback, and curriculum revision can enhance its coherence and practical applicability.

From the perspective of policymakers, it is recommended to organize in-service training programs to enable educators to learn about cognitive classification systems, such as the SOLO Taxonomy, and to incorporate modules into teacher education programs that include writing and assessing learning outcomes aligned with cognitive taxonomies. These approaches can contribute not only to content proficiency but also to the systematic implementation of multidimensional strategies that consider students' thinking levels in curriculum development.

7. Declarations

7.1. Conflict of interest

The authors declare that they have no known competing financial interests, institutional affiliations, or personal relationships that could have appeared to influence the work reported in this paper.

7.2. Funding

This research received no external funding.

7.3. Author contributions (CRediT)

Caner Çabuk: Conceptualization; Methodology; Investigation; Data curation; Formal analysis; Writing—original draft; Writing—review & editing; Visualization.

Cengiz Özyürek: Conceptualization; Methodology; Validation; Supervision; Project administration; Writing—review & editing.

7.4. Data availability statement

Data are available from the corresponding author upon reasonable request.

7.5. Ethics approval

This study was conducted in accordance with ethical principles. As it is a document review study, ethics committee approval was not required.

7.6. Use of artificial intelligence (AI) tools

The authors disclose the use of AI-assisted tools in the preparation of this manuscript for language editing support. AI tools were not used to generate or alter empirical data, produce analytical results, or shape the study's core findings and conclusions. All AI outputs were reviewed and verified by the authors, who take full responsibility for the integrity, originality, and accuracy of the content.

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